

# 山西垣曲河堤组寨里段的低等 四足类动物群

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**关键词** 山西垣曲 晚始新世 蜥蜴及鳄类化石

## 内 容 提 要

本文记述了我国晚始新世的一低等四足类动物群,包括三种蜥蜴和两种鳄类。其中的宽额半鳄蜥 (*Hemishinisaurus latifrons* gen. et sp. nov.) 是我国首次发现的异蜥科化石;垣曲响蜥 (*Tinosaurus yuanquensis* sp. nov.) 是响蜥属在我国的最晚代表。

八十年代后期,我所童永生、王景文对中国中、晚始新世哺乳动物群进行了大量的调查发掘和研究工作。与此同时他们在河南淅川、淅池,山西垣曲等地采集到了一批较为零散,但数量可观的爬行类材料。其中河南淅川中始新世核桃园组的材料已先期报道(李锦玲, 1991)。本文将就山西垣曲的材料作一简单介绍。

垣曲盆地地质工作的开展及脊椎动物化石的采集自 1921 年开始(周明镇等, 1973)。迄今,在河堤组寨里段已发现了哺乳类七属九种(童永生, 1989),而爬行类只有一鳖属 (*Trionyx* spp.) 被报道。新材料的发现无疑丰富了这一动物群的组成,为其时代的确定,及含化石地层的对比提供了进一步的依据。

## 一、蜥 蜴 类

Infraorder Lacertilia Owen 1842

Family Agamidae Gray 1827

*Tinosaurus* Marsh 1872

*T. yuanquensis* sp. nov.

**正模** 一对下颌的前段 (IVPP V9596.1)。

**副模** 一不完整的左上颌骨 (IVPP V9596.2)。

**归入标本** 十多块带有牙齿的颌骨 (IVPP V9596.3—15)。

**地点与层位** 山西垣曲,河堤组寨里段,晚始新世。

**特征** 下颌前部具 4 个侧生型锥状齿,第 4 齿硕大,为犬齿状齿。下颌外侧具齿间沟。上颌后部颊齿与下颌相对应,亦为三尖状齿。

**标本记述** 在山西垣曲河堤组寨里段,用淘洗法获取的砂样中含有为数众多,但保存不佳的蜥蜴颌骨。颌骨一般不完整,通常带有 2—4 个牙齿。牙齿的形状和排列方式都与发现于安徽潜山古新统的痘姆响蜥 (*T. doumuensis* Hou 1974) 十分相似。同一地点,同一层位的灰色粉砂岩中保存有一蜥蜴的左上颌骨和一对下颌支的前段。它们很可能并不属同一个体,但没有理由认为它们代表不同的种。它们的特征足以区别于响蜥的任一其它种,因此被选为新种的副模和正模。

上颌齿列前端缺失,现保存有 8 个牙齿,它们都极为侧扁。保存的前 3 齿单尖,扁锥状。保存的第 4 齿主尖两侧开始出现前后小尖的雏型。保存的第 5 至第 8 齿为发育完好的三尖状齿。

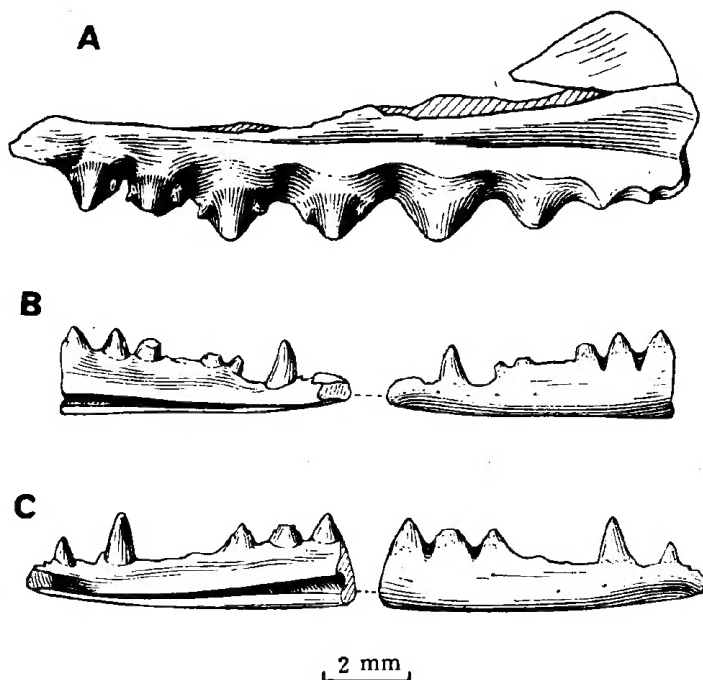


图 1 (Fig. 1) 垣曲响蜥 (*Tinosaurus yuanquensis* sp. nov.)

- A. 左上颌骨内侧视 (Internal view of left maxilla IVPP V 9596.2)  
 B. 左下颌支前端内侧、外侧视 (Internal and external views of left mandible, IVPP V9596.1)  
 C. 右下颌支前端内侧、外侧视 (Internal and external views of right mandible, IVPP V9596.1)

下颌前部纤细,缝合部短,麦氏沟张开。每侧的前部有 4 个侧生型的锥状齿,其后为一段齿缺,再向后为端生型的颊齿。下颌齿列不完整,前端只有左侧的第 4 齿和右侧的第 2、第 4 齿完整保存,其余的牙齿齿冠断失。从保存的情况判断,第 1—3 齿细小,第 4 齿硕大,为犬齿状齿。颊齿齿列后端缺失,与上颌的情况一致,前面的 4—5 齿单尖,后部的为三尖状齿。下颌外侧颊齿间有明显的齿间沟,这一特征过去只发现于美洲的材料。

**讨论** 响蜥广布于北半球的始新统,自 1872 年建立该属以来,已有 6 个种被报道。遗

憾的是虽然化石材料为数众多,但都较破碎,一般仅以一段带有三尖状牙齿的颌骨为代表。以致于到目前为止尚无法确定该属完整的鉴定特征。除了地理及地史分布的不同之外,各种之间以细小的牙齿结构上的差异相区别。

除了垣曲响蜥之外,痘姆响蜥的材料最为完整。这二者齿骨齿的形状与颊齿排列的疏密也十分相似。它们的区别在于痘姆响蜥的上颌颊齿单尖,侧视为等腰三角形,且大小相等(侯连海,1974)。而垣曲响蜥的颊齿自前向后逐渐加大,且三尖齿逐渐完善。上颌齿列的最后端为一小的三尖状齿,推测为新生齿。这两个种的区别之二是痘姆响蜥的前4个侧生型齿大小相近,不具增大的第4犬齿状齿。区别之三是痘姆响蜥的下颌外侧不具齿间沟。

响蜥的其余4个种都是在化石材料相当不完整的基础上建立的。发现于内蒙萨拉木仑中始新统的亚洲响蜥(*T. asiaticus* Gilmore 1943)牙齿排列紧密,齿冠圆钝。而河南卢氏中始新统的卢氏响蜥(*T. lushiensis* Dong 1965)颊齿呈雁行状排列,前一齿的后小尖与后一齿的前小尖内外错开。这两种也都不具下颌外侧的齿间沟。*T. stenodon* Marsh 1872 和 *T. pristinus* Leidy 1872 同产于美国怀俄明的中始新统。Gilmore (1928)在“北美的蜥蜴化石”一书中强调前者比后者大,牙齿更为粗壮,齿骨齿可以不具或具有1—2个侧小尖。而后者较小,牙齿的中央主尖圆锥状,除了第1个齿骨齿外其余均为三尖状齿。受材料所限,这4个种的特征似乎都不是确定无疑的。如 *T. stenodon* 的正模仅为一段带有两个牙齿和一个齿基部的颌骨,它与其它种的区别很可能是由化石的保存部位不同造成的。

### Infraorder Anguimorpha Furbringer 1900

#### Family Xenosauridae Cope 1886

#### *Hemishinisaurus* Gen. nov.

#### *H. latifrons* sp. nov.

**正模** 一不完整的额骨及一对前额骨 (IVPP V9595.1)。

**副模** 一左上颌骨前端 (IVPP V9595.2)。

**地点与层位** 山西垣曲,河堤组寨里段。晚始新世。

**特征** 额骨单一,眶间部较宽。表面雕饰粗大。单个雕饰长丘状,纵行排列,呈以中线为对称的叠瓦状分布。顶孔前置,位于额骨—顶骨缝合线上。

**标本记述** 单一的额骨保存不完整,前端及右后角缺损,保存部分近于梯形。梯形的两侧边呈舒缓的弧状,两前角与前额骨相接的部分凹入。额骨的保存长度10毫米,眶间宽度7毫米。相对较大的眶间宽度,暗示这一额骨的形态有别于其它异蜥类钟漏状(hour-glass-like)的额骨。“梯形”的底边——额骨与顶骨的骨缝平直,只是在中线附近额骨伸出两个小的后突,环围着一弧形面,它似乎标示着顶孔的位置。总体来看,骨片的两侧缘稍高,中间较低,为一纵向下凹的骨片。

额骨表面具规则分布的雕刻纹饰。单个突起一般纵向拉长,且左右不对称。严格地说单个突起的形态并不完全相同,靠近中线部位的为长丘状,而两侧的突起明显地向外侧倾斜,且顶端有小的锯齿状结构。总体来看,突起排列为纵行,呈以中线为对称的叠瓦状

分布。在眶间部每侧 4 行。

一对前额骨保存完好, 它与额骨前侧的边缘线大致吻合, 显示了它们确来自同一个体。前额骨形态不规则, 表面纹饰与额骨相似, 只是突起排列得更为密集。

左上颌骨保存极不完整, 从大小及表面结构推测它与正模也属同一个体。骨体下部的外表面光滑, 而上部具雕饰的长形突起。上颌骨的前缘形态显示该动物有一大的外鼻孔。第 1 及第 2 上颌齿保存, 牙齿亚端生型, 为略侧扁的锥状。

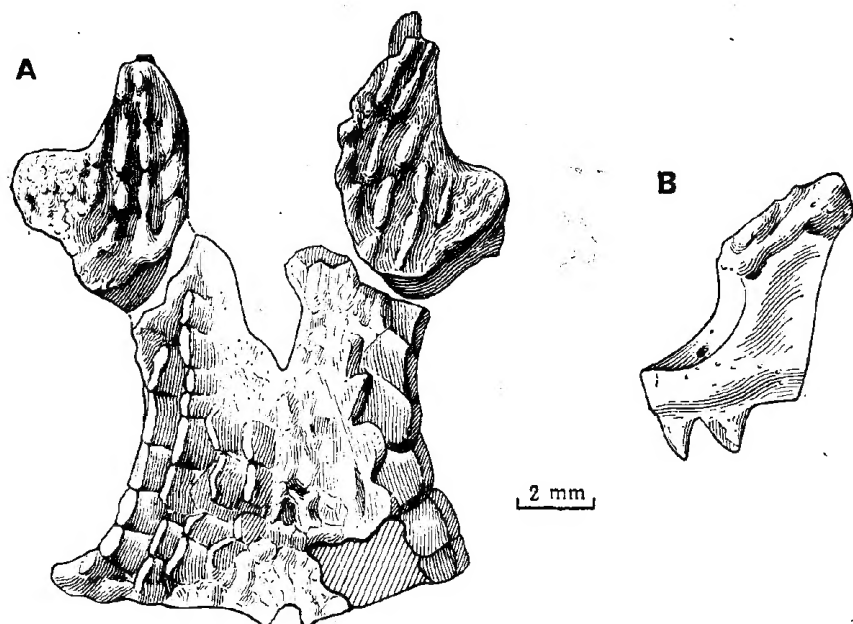


图 2 (Fig. 2) 宽额半鳄蜥 (*Hemishinisaurus lasifrons* gen. et sp. nov.)

A. 额骨及前额骨顶视 (Dorsal view of frontal and prefrontals, IVPP V9595.1)

B. 左上颌骨前端外侧视 (Lateral view of anterior end of left maxilla, IVPP V9595.2)

**讨论** 宽额半鳄蜥化石保存不够完整, 目前依据头骨上极具特色的雕刻纹饰, 将它和异蜥科 (*Xenosauridae*) 联系在一起。该科另外的两个化石属 *Exostinus* 和 *Restes* 都发现于北美, 时代自晚白垩世至渐新世, 它们的材料同样破碎和不完整。

这三属的头骨都具愈合的骨质甲片, 表面呈粗大的雕刻纹饰。虽然它们的细部结构不同, 但显然有别于蛇蜥科 (*Anguidae*) 成员的由细小颗粒所装点的甲片。Gauthier (1982) 在建立 *Restes* 属时强调其头顶雕饰由一些平的镶嵌体所组成, 它们为一些窄沟所分割。*Exostinus* 的雕饰是由彼此相隔甚宽的圆锥体所组成, 它们在额骨的眼眶边缘常常互相结合成嵴。而宽额半鳄蜥的雕饰呈长丘状, 向两侧倾倒, 呈叠瓦状分布。

一般说来, 宽额半鳄蜥的额骨较宽, 与其它异蜥类不同, 在眼眶间并未强烈收缩。它的额骨后缘象其它异蜥类一样是平直的, 只是在中线附近两个小的突起和其间的弧形凹入似乎标示着顶孔位于额骨及顶骨的骨缝上。此点有别于异蜥类的其它成员, 它们的顶

孔无例外地位于顶骨的前部。

宽额半鳄蜥仅保存了左上颌骨的一小部分,它与 *Exostinus serratus* 上颌骨的相同部位十分相似。但二者的牙齿有较大差异。据记载 *Exostinus serratus* 的牙齿侧生型,具初生的前小尖。

中美洲的 *Xenosaurus* 和我国广西瑶山的 *Shinisaurus* 是异蜥科仅有的两个现生成员。这两属的地理分布相距遥远,形态差异也较大,众多的研究者倾向于将二者归于同一科,甚至于同一亚科。但 Estes (1983) 认为虽然这两属的形态差异可以由二者不同的生活习性所造成,但它们的相似性并不足以证明这是一个单源类群。

宽额半鳄蜥的发现,扩展了异蜥科的地理分布范围,有助于人们对这一科的认识。在中国这是除现生鳄蜥之外唯一的化石材料。虽然在如此破碎化石的基础上讨论其系统发育关系是不稳妥的,但由于地理分布的靠近,鳄蜥与半鳄蜥,可能较与该科的其它成员有更近的亲缘关系。

### Infraorder Scincomorpha Camp 1923

#### Family Scincidae Gray 1825

#### Gen. et sp. indet.

在河堤组寨里段地层中用淘洗法获取的材料中,除丰富的哺乳类外,还有十多块带侧生型齿的蜥蜴颌骨(IVPP V9597)。牙齿的形态既不同于 *Hemishinisaurus* 和 *Tinosaurus* 的牙齿,也明显地有别于中国目前已发现的任何蜥蜴化石。

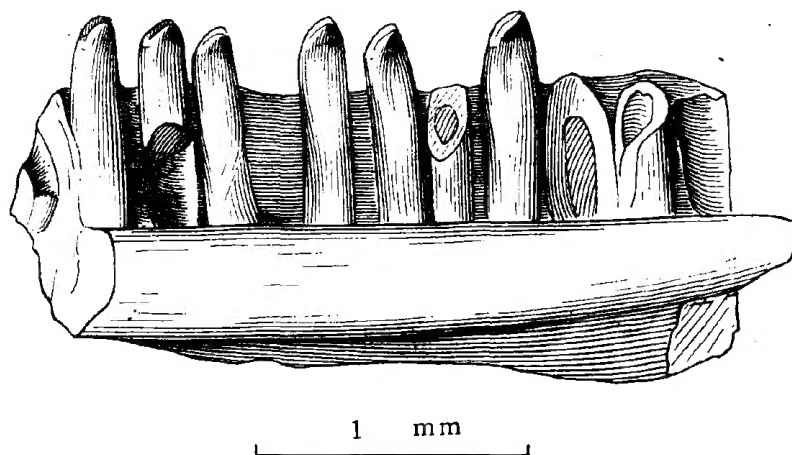


图3 (Fig.3) 石龙子类化石 下颌内侧视 (Internal view of an incomplete mandible of a scincid, IVPP V9597.1)

这一蜥蜴的特征可以以 V9597.1 为例记述如下:V9597.1 为一段下颌,长 2.8 毫米,有 12 个齿位,保存有 6 个近于完整的牙齿。牙齿排列较密,齿高 0.8 毫米。齿干直,横切面椭圆形,前一后向稍侧扁。牙齿单尖,齿尖偏向后侧。齿冠的唇面光滑,圆弧状;舌面有浅的纵纹。纵纹之下隐约可见一横向的印记。

这一蜥蜴牙齿的形态、排列及着生方式都与石龙子科的成员极为相似,特别是美国加

利福尼亚上始新世梅森河谷组 (Misson Valley Formation) 的 *Paracontogenys*。后者的齿尖虽然前后等高, 中间为一浅凹相隔, 齿尖内侧也有小的纵纹。

## 二、 鳄 类

### 1. *Crocodylidae* gen. et sp. indet.

山西垣曲的鳄类材料极不完整, 除了用淘洗法获取的几十个细小的牙齿之外, 仅发现了一块颧骨和一段带有两个半牙齿的上颌骨 (IVPP V 9598)。这些材料标示着一个小型真鳄类的存在。牙齿单尖, 内弯, 前后对称, 前后缘上不具锯齿结构。少量牙齿粗壮, 短小且圆钝, 为齿列后部的牙齿。这些牙齿的形态、大小与河南淅川中始新统核桃园组的材料 (见李锦玲, 1991) 完全相同。虽然鳄类的牙齿不具鉴定意义, 不能作为确定种属的依据, 但它们在大小形态上的极度一致, 似乎暗示着有同一种鳄类存在于这地理、地史分布都相距不远的两个点上。

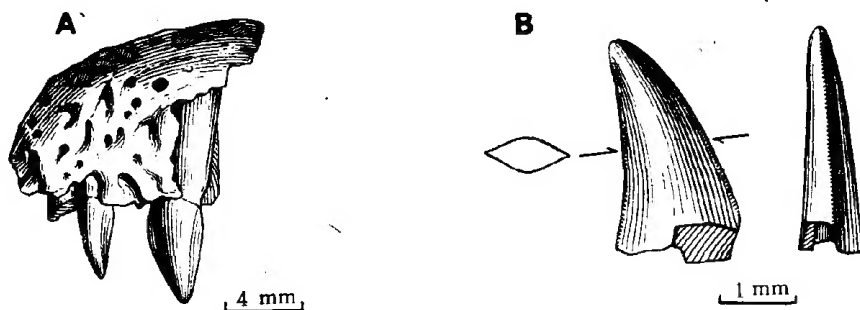


图 4 (Fig.4) A. 鳄类—左上颌骨前端 (The anterior end of left maxilla of an eusuchian, IVPP V9598)

B. 一剑齿 (A ziphodont tooth, IVPP V9599)

### 2. *Ziphodont* tooth

在垣曲的材料中, 仅有一枚鳄类的牙齿 (IVPP V9599) 与众不同。它既不同于一般鳄类的牙齿, 也有别于已记述过的中国所有鳄类的剑齿。这一牙齿是目前中国所发现的最小, 也最为侧扁的剑齿。齿冠长 2.5 毫米, 基部宽 1.7 毫米。它的唇舌面对称, 齿尖弯向后方, 前缘长于后缘。牙齿极为侧扁, 内外侧厚度仅为 0.75 毫米。齿基部厚与宽之比为 0.44。这大大地小于任一淅川剑齿的同一比值。在淅川所测量的 9 个牙齿中, 仅有一齿其比值为 0.57; 5 齿为 0.6—0.7; 3 齿大于 0.8。垣曲剑齿前后缘上锯齿状小齿的密度也最大, 为每毫米 7—9 齿。值得注意的是垣曲材料虽然在大小上不同于任何已知的剑齿, 但它齿冠基部的侧扁度及前后缘上锯齿状小齿的密度却与 Langston (1956) 所记述的哥伦比亚及阿根廷的某些 *Sebecus* 的牙齿极为相似。

### 三、几点初步的认识

我国始新世低等四足类动物群的研究工作还刚刚起步。目前正处于化石的发现和报道阶段。由于材料的不够完备,全面的综合性研究对比似为时尚早。垣曲动物群的发现无疑地充实了我们对这一时期动物群面貌的认识,为大陆间的横向对比,及我国中部地区的纵向对比提供了条件。

垣曲晚始新世与浙川中始新世低等四足类动物群有很多相似之处。到目前为止,二动物群的组成数量几乎一致。它们都由 1 种龟鳖类、3 种蜥蜴和 2—3 种鳄类组成。

浙川发现的蜥蜴中具地方特色的,同时也是化石材料较丰富的浙川短齿蜥 (*Brevi-densilacerta xichuanensis* Li 1991) 和河南密齿蜥 (*Creberidentat henanensis* Li 1991) 在垣曲动物群中没有出现,代之以异蜥科的新成员宽额半鳄蜥和石龙子类。蜥蜴中只有响蜥一属是两个动物群所共有的。有趣的是浙川的响蜥材料与同时代的(中始新世)卢氏响蜥相似,被定为 *Tinosaurus* cf. *T. lushiensis*。而晚始新世寨里组响蜥属的新成员 *T. yuanquensis* 却显示了与安徽古新世 *T. doumuensis* 的相似性。

两动物群中都有小型鳄类的牙齿,它们大小、形态的一致似乎表明它们可能来自同一种鳄类。如果这一推测能得以证实,那它将是将这两个动物群联系在一起的唯一的同一种动物。鳄类的剑齿也存在于这两个动物群中。但浙川的剑齿较粗大,边缘小齿的密度小,它很可能属真鳄亚目。而垣曲的剑齿细小,边缘小齿的密度大,与美洲西贝鳄亚目 *Sebecus* 的牙齿显示了极大的相似性。

垣曲动物群与北美加利福尼亚中一晚始新世动物群 (Golz and Lillegraven, 1977) 的对比表明,前者的组成成份显然大大地少于后者,除了无法详细鉴定的真鳄类材料和鳄类剑齿外,二者之间不仅共有一属蜥蜴 *Tinosaurus*, 还共有一属鳖类 *Trionyx*。这一情况似乎是由 *Tinosaurus* 和 *Trionyx* 的世界性分布所造成的,并不意味着垣曲动物群与加利福尼亚动物群,比与浙川动物群之间有着更大的相似性。

笔者对提供化石材料的童永生、王景文同志,及绘制插图的胡惠清同志致以诚挚的谢意。

(1991 年 1 月 12 日收稿)

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## FOSSIL REPTILES FROM ZHAILI MEMBER, HEDI FORMATION, YUANQU, SHANXI

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**Key words** Yuanqu, Shanxi; Late Eocene; Lizard and crocodile

### Summary

The geological investigations and fossil collections started in 1920s' and have been carrying on intermittently until now at Yuanqu, Shanxi province, have proved that Zhaili member Hedi Formation is rich in fossil vertebrates — not only in mammals, but also in reptiles. Nevertheless only a turtle, *Trionyx* spp. has been so far reported.

The present paper deals with the materials of reptiles obtained in the late 1980s'. Although the specimens are abundant, most of them are dissociated and fragmentary bones or isolated teeth and can not be recognized on species or even generic level. The assemblage, being the second Eocene reptile fauna in China, consists of a turtle, 3 lizards and 2 crocodiles. A new genus and 2 new species are here described. Coexisted with the terrestrial lower tetrapod fauna are such mammals as primitive cricetids, zapodids and abundant anthracotheres in Late Eocene Zhaili Basin (Tong, 1989).

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### Lacertilia

#### Agamidae

#### *Tinosaurus yuanquensis* sp. nov.

**Holotype** A pair of anterior portion of mandibles (IVPP V 9596. 1).

**Paratype** An incomplete left maxilla (V 9596. 2).

**Referred specimens** Some jaw bones with teeth (V 9596. 3).

**Locality** Yuanqu, Shanxi Province.

**Horizon** Upper Eocene, Zhaili member, Hedi Formation.

**Diagnosis** First four teeth of lower dentition conical and pleurodont. The 4th tooth caniniform. Vertical grooves between teeth on external side of lower jaw present. Upper cheek teeth tricuspid.

**Remarks** Since the genus *Tinosaurus* was established in 1872, 6 species have been reported from the northern hemisphere. In view of the fragmentary specimens on which the



knowledge of *Tinosaurus* is based, the generic diagnosis is far from certain.

In some respects, such as the shape of lower tooth and the arrangement of tooth, the new species *T. yuanquensis* is closely related to *T. doumuensis* from the Paleocene Doumu Formation of Anhui. Significant differences that can serve to distinguish the two taxa may be as follows: the upper cheek teeth of *T. yuanquensis* are tricuspid, perfected gradually and increased in size from the fore to the last, while they are single cusp, isosceles triangle in lateral view and equal sized in *T. doumuensis* (Hou, 1974); The first four teeth on lower jaw are almost equal sized and pleurodont in *T. doumuensis*, when the 4th tooth in *T. yuanquensis* is caniniform, much larger than the first three teeth. The presence of vertical grooves between teeth on external surface of lower jaw is commonly known in the North American species, but never seen in the other Chinese species. If the grooves are caused by wear of opposing upper teeth, as explained by Gilmore (1928), it is less important in fossil determination. *T. yuanquensis* also differs from *T. asiaticus* with blunter tooth crown and *T. lushiensis* with a more closely arranged dentition.

### Anguimorpha

#### Xenosauridae

#### *Hemishinisaurus latifrons* gen. et sp. nov.

**Holotype** An incomplete frontal and a pair of prefrontals (IVPP V9595. 1).

**Paratype** Anterior portion of left maxilla (V9595. 2).

**Locality** Yuanqu, Shanxi Province.

**Horizon** Upper Eocene, Zhaili member, Hedi Formation.

**Diagnosis** Single frontal with a rather wide interorbital region and a narrow anterior portion. Fused osteoderms bearing long hill-like tubercles arranged in longitudinal rows between the orbits. Parietal opening on the suture of frontal and parietal.

**Remarks** Instead of being hourglass-like as in all other xenosaurine, the frontal has a rather wide interorbital and narrow anterior region. There are two small processes near the mid-line on the straight posterior margin of the frontal, which may indicate the position of a parietal foramen. The osteoderms, in contrast to the subconical ones in *Exostinus* and *Xenosaurus* or flattened tesserae in *Restes*, are ornamented with long hill-like tubercles, which are arranged in longitudinal rows and slanted laterally. The lines formed by the longitudinal arrangement of osteoderms are symmetrical and look like being overlapped one another. The two prefrontals are supposed come from the same skull with the frontal. The osteoderms of the prefrontal are bearing slightly denser tubercles. The damaged left maxilla (V 9595. 2) can provide limited information about the animal. The surface of maxilla is smooth on the lower part, but ornamented with long hill-like tubercles on the upper part. The only two maxillary teeth are subacrodont and compressed conical. The anterior margin of the maxilla indicates the presence of a large external nares.

Although *Hemishinisaurus* has no hourglass-like frontal, the features of its osteoderms assume that *Hemishinisaurus* belongs to the family Xenosauridae. The family is small, poorly known and represented only by two living forms *Xenosaurus* and *Shinisaurus*, and two fossil genera *Exostinus* and *Restes* discovered from the Upper Cretaceous to Oligocene of North America. Gauthier (1982) distinguished *Restes rugosus* from *Exostinus* by having a flattened tesserae cephalic osteoderms rather than a subconical one. The differences in osteoderms

which distinguish *Hemishinisaurus* from all the other xenosaurs can also serve as a determination in generic level.

### Scincomorpha

#### Scincidae gen. et sp. indet.

Based on more than 10 jaw bones (V 9597) from Yuanqu locality, the third lizard is recognized. V 9597. 1, a portion of lower jaw (2.8 mm long) with 12 tooth position, and 6 complete pleurodont teeth left is described here as an example. The teeth (0.8 mm high) are small, slender and closely spaced. The tooth stem is straight, elliptical in cross section and compressed antero-posteriorly. The tooth crown with single cusp located posterior to the midline is smooth and curved on labial surface, but striated on lingual.

These specimens are referred to Scincidae because of the presence of pleurodont teeth and the striation on tooth crown. They seem to be most similar to that of *Paracontogenys* of the family in tooth shape, arrangement and the pattern of tooth plantation.

### Crocodylia

#### 1. Crocodylidae gen. et sp. indet.

Several dozen small crocodilian teeth, a jugal and an incomplete maxilla with teeth (IVPP V 9598) were collected from the Yuanqu locality. Most of the teeth are curved lingually, but symmetrical antero-posteriorly, bearing no serrations on tooth carinae, while some of the teeth in the back portion of dentitions have a short, round and stout crown. The teeth are almost identical in size and shape with those from the Middle Eocene, Hetaoyuan Formation of Xichuan, Henan (Li, 1991).

#### 2. Ziphodont tooth

The only ziphodont tooth (IVPP V 9599) found at the Yuanqu locality is small and most compressed. Its crown (with a length 2.5 mm, width at base 1.7 mm, and thickness 0.75 mm) is symmetrical linguo-labially and curved posteriorly. The ratio of tooth thickness to width is 0.44, much smaller than that of the teeth from Xichuan, based on the measurements of 9 teeth (0.57—0.80) (see Li, 1991). The density of serration of tooth carinae is 7—9 per millimeter. Notable is that the tooth is different from those of all the other Chinese ziphodont teeth, but similar to *Sebecus* from Colombia and Argentina in the ratio of thickness to width as well as the density of serrations (Langston, 1956).

The Yuanqu lower tetrapods fauna shows similarity to the Xichuan fauna in composition and variety. Both of them consists of a turtle, 3 lizards and 2—3 crocodiles. *Tinosaurus* is the only lizard genus which was discovered in both faunas. It is noteworthy that the materials from Xichuan are referred to *Tinosaurus* cf. *T. lushiensis*, a species also known in the Middle Eocene, while *T. yuanquensis* from Yuanqu shows similarities to the Paleocene *T. doumuensis* from Anhui. The unique described new genus *Hemishinisaurus* of Yuanqu fauna is the first fossil xenosaurs recognized in China. The relationships of this genus to the living xenosaurs remains obscure for the fragmentary specimens of the fossil form, but the problem is no doubt fascinating.